Editorials

Validation – The Missing Link in Life Cycle Assessment

Towards pragmatic LCAs

Andreas Ciroth[1]* and Henk Becker[2]

[1] GreenDeltaTC GmbH, Raumerstr. 7, 10437 Berlin, Germany
[2] Utrecht Centre for Applied Sociology, Woestduinlaan 65, 3941 XC Doorn, The Netherlands

* **Corresponding author** (ciroth@greendeltatc.com)

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The Life Cycle Assessment methodology has been astonishingly successful over the past decade. LCA, the concept, has been standardised, the number of conferences and publications have increased and the activities on the European level (e.g. LCA platform and others) proliferate. However, we assert that the power of, and value delivered by, LCA would increase significantly if it were validated. **Validation**, you may recall, is *"the process of ascertaining that the model mimics the real system by comparing the behaviour of the model to that of the real system in which the system can be observed and altering the model to improve its ability to represent the real system"* [1]. In other words, you check whether the model you have built is correct by comparing it to the reality you attempted to model. This editorial will make the case that, in addition to aligning LCA with a more rigorous scientific approach, ensuring cases are validated can provide benchmarks and, when coupled with sensitivity analyses, enhance the practicality of the method. While validation may seem like one additional step in a tool which is already too comprehensive, it could, on the other hand, and as the authors believe, make a convincing case that carrying out LCA contributes, or could, to sustainability.

1 Validation of LCA Models is Not Yet Complete

We need to explain why we think that validation is missing, and why this is a flaw. Let us begin with the first question and sketch out an answer using the example of building a ship. Imagine a group of engineers that are to build a fast and reliable racing yacht. The ship needs to be made from many different components (sail, mast, hull, keel, canvas, and so on). As they want to build a winning boat, the engineers use only high-quality, or light-weight components, which have been thoroughly tested, individually. They also have asked experts for their opinions and follow their, sometimes diverse, advice as well as possible balancing various constraints (**Fig. 1**).

Quite often, despite the best efforts, and the testing of the prototype, even designs with essentially limitless budgets (e.g. 12-meter boats) require re-engineering prior to achieving their target specifications. The essential conclusion would be, therefore, that the ultimate result must be validated, despite the, often quite extensive, checks in background data, assumptions, material properties and performance. One can no more, quantitatively, model a boat than an environmental assessment. Indeed, the best models, those to which precision exceeds ten decimal places, tend to relate to very specific materials or sub-atomic particles, not complicated composites or devices.

Therefore, this boat-building exercise is very similar to building an Life Cycle Assessment model. In a high quality LCA study, one may

– combine the best process data and impact assessment models available,
– make sure that these 'components' are thoroughly tested, and

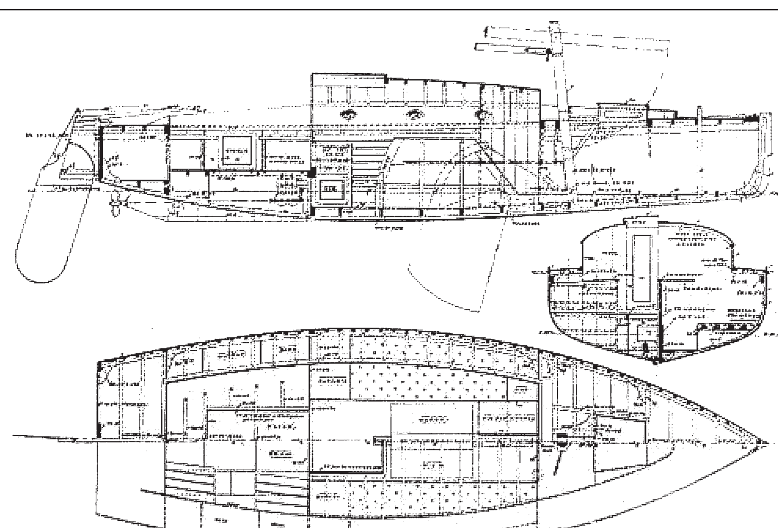

Fig. 1: Einstein's 'Tümmler' Yacht from 1929, a sailing ship (Picture by courtesy of Delius Klaesing Verlag, Die Yacht)

– pay attention to the fact that the components as well as the design and the approach of the study reflect up-to-date knowledge and advice of high-level experts.

There are many other possible examples; writing without being able to see the writing, and speaking without being able to listen to one's own speech, are two other striking ones.

Building an LCA model. The difference between a sailing ship and an LCA study is that there are many yachts that have already passed the test and proven to be fast and reliable, while a complete LCA has never been tested. For a yacht, the risk one takes is in reducing weight to extremes with new, untested, materials, in adding electronics and in improving adaptability to various water or wind conditions. In this sense, being on the cutting edge introduces its own uncertainties. LCAs, still, calculate potential environmental impacts of products, and these potential impacts have not yet been validated. We refer to the overall outcome of the study, not to data on individual unit processes. There is no check whether the output of the model may or may not match the output of the real system. Thus a validation, which would be such a check, is missing. In this sense, the LCA is the best case model given the resources at hand. For a full LCA study, the analogy to the racing yacht is a good one as resources are almost left out of the equation. In designing more commonplace items (such as Einstein's yacht in Fig. 1), or in carrying out practical, or screened, assessments, the need for validation becomes even more acute.

2 Why is Missing Validation a Flaw?

As long as there exists sufficient belief that the calculated outcome and the recommendations from LCA studies are justified, and as long as they are actually justified, missing validation may not be problematic. However, note that, to a certain extent, 'belief' is needed for applying an LCA. Let's analyse this in more detail. Why is missing validation a flaw?

From a scientific standpoint, the LCA method lacks empirical validation concerning its most important part, the overall result (**Table 1**). This statement deserves certainly further explanation, which will be provided later.

Let's, for now, rather address the practical consequences. From a practical side, a model that is not tested has a result that is not 'tangible' and may be questioned only in terms of:

– the modelling procedure (*how the ship is built*)
– comparison to other, similar models (*whether the ship looks similar to other ships*).

Thus, following the modelling rules, becomes perhaps more important than the result of the model itself. One might say that, following the rules, becomes the goal. Deviations from accepted rules (either refinements or simplifications) need to be plausible or attractive to gain acceptance, and need not necessarily be an improvement in relation to the model result. This implies of course the danger of building ships that do not float, and of subsequent procedures that are not relevant for a successful boat.

For LCA studies, it is proposed

– to model changes over time (though it is not often done),
– to consider uncertainties in LCA (which is not done on a routine basis), and
– to consider whether the decision under study changes the decision environment (→ marginal, change-oriented vs. attributional LCA).

For simplifications in LCA, on the other hand, the environmental impact of many product systems is dominated by their energy demand, and many other material flows often need not be modelled to decide about the overall environmental performance of the product system.

Without looking at the effect in reality, these changes in modelling can barely demonstrate why and how far they are useful. Most important, perhaps, is that LCA models are models in a quickly changing world, and, with the tendency of being rather complicated for far-reaching decisions, they imply the danger to be relied upon for too long.

In summary, we think that in the early nineties the retreat to the model – to modelling potential environmental impacts instead of 'real cases', the move to accounting models, attributional models, built from unit process descriptions of 'what-is' rather than predictive models that attempt to describe 'what-if' – was smart and well justified; it made the whole, visionary life-cycle concept applicable. Today, however, we find the situation different.

What we perceive from reality should be the primary criterion for deciding about LCA modelling. An LCA model should reflect reality as good as possible and necessary. What is actually needed is determined by the decision situation and by goal and scope of the study. In order to be able to assess whether an LCA model reflects reality, validation approaches need to be fostered. Some have been proposed for LCAs [5,6], though not yet applied. They are inexistent today (for LCAs!).

3 Possible Objections and Tentative Responses

We suspect the following three objections:

1. That is not possible
2. That is already done
3. That does not add anything of value

As we find these objections not justified, we are going to argue against them in the following.

Table 1: Features of science, political analysis and life cycle assessment in comparison

Features of science [2]	Features of policy analysis [2]	Features of Life Cycle Assessment [3]
Empirical testing	Testing often impractical	Empirical testing only for single elements of LCAs, if any (e.g. Impact Assessment models may have been tested empirically), no empirical tests for the overall LCA model
Full documentation	Documentation typically inadequate	Full documentation (desired)
Reporting of uncertainty	Uncertainty usually incomplete or missing	Uncertainty usually incomplete or missing; in part a flat estimation of uncertainty
Peer review	Review not standard and in some cases arduous	Review is standard for comparative assertions, review for single datasets under development
Open debate	Debate hindered by the above problems	Open debate (sometimes hindered by confidentiality and data issues)

3.1 That is not possible

We are aware that 'listening' to LCA results requires, today, pioneering work. This objection is thus quite relevant. However, recent developments are encouraging.

- *Data availability* has increased significantly since 1990, not only with regard to inventory data for processes and impact assessment models (ecoinvent, NREL, ProBas), but also to many different data on local and global scale.
- *New modelling methods* have emerged, or existing ones have not yet been applied for LCAs. One example from sociology: In social surveys, data gathering was possible on a large scale, but the scope of each set of data on the social behaviour of an individual was very limited and did not provide information on the validity of the data. In participant observation, data gathering was rich in detail, information on validity was available, but the number of participant observations in a research project had to be restricted to not more than about eight cases. Becker developed a method that combined the large scope of surveys, the in-depth data gathering of participant observations and the explanatory control of the validity of the data gathered. He called this new method 'observation by informants' [4]. The research method of 'observation by informants' could provide LCA with the possibility to gather data in detail on the social behaviour of large numbers of individuals, in institutionalised setting, and over a relatively long period of time. This method enables LCA researchers to test their models by distinguishing time periods and to apply an explanatory theoretical model to test the validity of its model by predicting outcomes from period 1 to period 2, from period 2 to period 3, and so forth. The approaches need not be complicated or tedious. Some examples have already been proposed for LCAs [5–6].
- *Emerging awareness and experiences in other applications*. In military planning, 'effects based operations' have obtained high attention in the last few years, dealing in fact with an assessment of the effects caused by decisions:
  "Effects-based operations are operations conceived and planned in a systems framework that considers the full range of direct, indirect, and cascading effects, which may – with different degrees of probability – be achieved by the application of [different sorts of] instruments" [7].
  Several large projects have been funded in the past years on effects-based operations, and congresses are dedicated to this issue. Although, of course, discussed in a different setting, many of the ideas and solutions seem applicable for environmental impacts.
- *Single criteria for effects in reality can suffice*. It seems not necessary to provide a full picture of the effects of a decision; quite often, indicators will suffice. These indicators can comprise results obtained from other, comparable methods (the so called 'triangulation' concept in social sciences); they can also consist of indicators in the narrow sense that cover only small 'bits' of reality. This makes the overall task easier.

3.2 That is already done

Although there have been performed, of course, quality checks by LCA experts, they are not performed with the aim of addressing the effect of a decision in reality. Even if it is possible to assess single components of an LCA (the material balance in the inventory; one unit process inventory), this resembles a test of the single components of our ship. So we think this has not yet been done.

3.3 That does not add anything of value

Feedback and validation are key elements of scientific thinking and of every-day life. They are central elements for a reliable, efficient modelling in systems engineering and control theory. Including both, in a systematic manner, in the Life Cycle Assessment approach promises so many advantages that this objection does not seem justified.

Concluding, we think that introducing validation in LCA models offers tremendous possibilities for model improvements as well as improvements of the quality of decisions supported by LCA models, namely of a potential still untapped yet. It can also offer practitioners a means to benchmark their studies against existing ones, similar in regards to certain key constraints.

Before any sophistication of LCA models is introduced, and there are many additional features 'waiting' to be incorporated – may it be rebound effects, marginal or consequential modelling, time, and even, to some extent, uncertainties – the first step should be to care about the effects: Which improvement would the outcome achieve? Why and when is it relevant?

New features should be introduced *only* if they are relevant, and only when they are relevant. And so, in order to be able to judge about the relevance, the effect of a proposed change should be addressed in the first place.

This calls for a development of techniques capable to assess the effects of an LCA model in reality. That could be rendered by pragmatic Life Cycle Assessments.

Call for comments. We would like this editorial to initiate a discussion on possibilities of pragmatic LCAs, and therefore conclude with a call for feedback and comments.

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References

[1] Biles WE (1996): Discrete-Event Systems. In: Khair NA, Systems Modelling and Computer Simulation. Marcel Dekker, New York, p 220
[2] Morgan MG, Henrion M (1990): Uncertainty – A guide to dealing with uncertainty in quantitative risk and policy analysis. Cambridge University Press, NY, p 22
[3] Ciroth A (2006): Input data quality, data validation, uncertainty in LCA. Input paper for the SETAC UNEP task force 3, methodological consistency, August 2006
[4] Becker HA (1972): Observation by informants in institutional research. Quality and Quantity VI (1) 157–169
[5] Ciroth A (2002): Case Studies in Life Cycle Assessments – Their role, misunderstandings, improvements. Demonstrated on a case study for plastics waste disposal. Platform presentation, 10th SETAC Case Study Symposium, Barcelona, 2 December 2002
[6] Ekvall T (2006): Calculation errors in Life Cycle Assessments. Platform presentation, 16th SETAC Annual Meeting, Den Haag, May 2006
[7] Davis PK (2001): Effects-Based Operations. A Grand Challenge for the Analytical Community. Rand Corporation, p 7

Further Literature on 'Validation'

Yannopoulos P (2006): Sulfur Dioxide Dispersion and Source Contribution to Receptors of Downtown Patras, Greece. Environ Sci Pollut Res, OnlineFirst <DOI: http://dx.doi.org/10.1065/espr2006.06.319>
Schröder W, Pesch R (2005): Time Series of Metals in Mosses and their Correlation with Selected Sampling Site-Specific and Ecoregional Characteristics in Germany. Environ Sci Pollut Res 12 (3) 159–167